

# REPORT DOCUMENTATION PAGE

Form Approved  
OMB No. 0704-0188

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1. Agency Use Only (Leave blank).		2. Report Date. July 11, 1989		3. Report Type and Dates Covered. Proceeding July 11, 1989	
4. Title and Subtitle. A Hough Transform Technique For Extracting Lead Features From Sea Ice Imagery				5. Funding Numbers. Program Element No 62435N Project No 13219R Task No MOG Accession No DN256010	
Author(s). Florence M. Fetterer and Ronald J. Holyer				8. Performing Organization Report Number. PR 89:034:321	
Performing Organization Name(s) and Address(es). Naval Ocean R&D Activity Code 321 SSC, MS 39529-5004				10. Sponsoring/Monitoring Agency Report Number.	
Sponsoring/Monitoring Agency Name(s) and Address(es). Office of Naval Technology					
Supplementary Notes.					
12a. Distribution/Availability Statement. Approved for public release; distribution is unlimited.				12b. Distribution Code.	
13. Abstract (Maximum 200 words). Infrared imagery from polar-orbiting satellites provides a synoptic and long-term view of lead patterns in Arctic pack ice. The large quantity of satellite data in image form suggests the use of automated methods for compiling lead statistics from imagery. A Hough transform technique for the semi-automated extraction of lead orientation and spacing is described and first results are presented.					
14. Subject Terms. Sea Ice, Leads, Hough Transform, AVHRR				15. Number of Pages. 4	
				16. Price Code	
17. Security Classification of Report Unclassified	18. Security Classification of This Page. Unclassified	19. Security Classification of Abstract. Unclassified	20. Limitation of Abstract		

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# A HOUGH TRANSFORM TECHNIQUE FOR EXTRACTING LEAD FEATURES FROM SEA ICE IMAGERY

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## ABSTRACT

Infrared imagery from polar-orbiting satellites provides a synoptic and long-term view of lead patterns in Arctic pack ice. The large quantity of satellite data in image form suggests the use of automated methods for compiling lead statistics from imagery. A Hough transform technique for the semi-automated extraction of lead orientation and spacing is described and first results are presented.

KEY WORDS: SEA ICE, LEADS, HOUGH TRANSFORM, AVHRR

## 1. INTRODUCTION

Sensors on polar-orbiting satellites produce digital imagery with which the regional, seasonal, and annual variability of large-scale lead patterns in Arctic pack ice can be studied. The infrared AVHRR sensor on board the NOAA series is well suited to this task because of its nearly arctic-wide swath and revisit frequency of several times per day. Thermal data offers day and night, year-round coverage. However, cloud contamination is often a problem at high latitudes, and because AVHRR imagery has a resolution of 1 km at nadir, only large leads are resolved. Within these limitations, characteristics of a lead ensemble such as average lead width, length, spacing and orientation can be obtained from imagery and related to atmospheric and oceanic stress fields and to surface fluxes.

Satellite remote sensing provides the spatial and temporal coverage necessary to compile a climatology of lead characteristics. With this advantage comes the task of extracting lead features from large amounts of image data. Here a method for the semi-automatic extraction of lead orientation and spacing from binary images of leads is presented. Although demonstrated with AVHRR imagery the technique is suitable for any digital imagery in which lead pixels can be distinguished from background pixels.

## 2. THE HOUGH TRANSFORM

The Hough transform is a computer vision technique for detecting lines, circles, or other shapes in imagery. Recently it has found application in remote sensing (Cross, 1988), where its speed, flexibility in extracting shapes, and relative insensitivity to image noise makes it an attractive alternative to other methods for object recognition. To implement the transform, an edge detector or other method for identifying leads is first applied to the image.

Each pixel of the image is classified as either a lead pixel or not a lead pixel. Pixels identified as lead pixels in image space are then mapped into "parameter space", where parameters are those which describe the shape being sought. Here, it is assumed that lead pixels are roughly collinear points, therefore the transform is employed as a line finder using the normal parameterization of a line

$$\rho = x \cos \theta + y \sin \theta$$

where  $\theta$  is the angle of a normal to the line and  $\rho$  is its distance from the origin (Fig. 1a). Parameter space is represented as an accumulator array of discrete  $\theta, \rho$  values. For an  $(x, y)$  image pixel,  $\theta$  is incremented from 0 to 180 in steps of one degree and  $\rho$  calculated for each  $\theta$ . Accumulator element  $(\theta, \rho)$  is incremented for each pair. Every lead point in the image is therefore transformed into a sinusoidal curve of 180 points in the accumulator, where each  $(\theta, \rho)$  element of the curve describes possible lines through that image point. If points in image space are members of the same line, curves formed by those points will cross in parameter space at the  $(\theta, \rho)$  element which describes the line (Fig. 1b). That element will have a higher value than surrounding elements in the accumulator array (Duda and Hart, 1972). The accumulator array can be thought of as a 2-d histogram of the frequency with which points occur on a given line. Peaks in the accumulator above a noise threshold correspond to lines in the image.

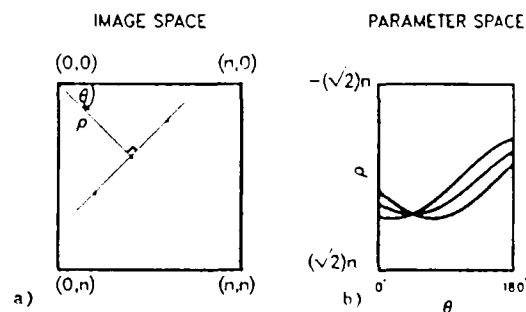


Fig. 1. The Hough transform maps points from image space (1a) into parameter space (1b). See text for explanation.

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### 3. APPLICATION TO LEAD FEATURES

#### 3.1 Test Images

Figure 2 shows the AVHRR image of the central Arctic from which test images 1-4 were selected. Image resolution varies with distance from nadir. For simplicity, we will assume a constant 1km per pixel. Leads are warmer than the surrounding ice, and therefore appear as dark lines in infrared imagery. Binary images were created from images 1-4 using an interactive detrending and thresholding procedure (Fig. 3b, 5a). This preprocessing step is critical, as the Hough transform will detect only those lines which appear in the binary image. Future work will seek to make this step less subjective and to preserve the distinction between new, dark leads and old, light leads which have a thicker ice cover. Fortunately, the Hough transform is insensitive to breaks in lead lines which are created in the thresholding process.

#### 3.2 Transform Procedure

Fig. 4a displays the accumulator for the image of Fig. 3b in image form. The resolution of each pixel is one degree in the  $\theta$  direction, and 2km in the  $\rho$  direction. Peaks, or bright points, in the accumulator give the angular orientation ( $\theta$ ) and normal distance to image origin ( $\rho$ ) for leads in the image. Because lead pixels are only approximately collinear, peaks will be spread over a cluster of points. An empirically chosen threshold was applied to the accumulator, and points with values above the threshold (shown in Fig. 4b) were inverse-transformed to determine how well leads in the binary image were detected (Fig. 3c). Parameter space carries no information on the position of line end points, therefore calculated lines are drawn with infinite length.

The inverse transform of all points in clusters with values above the threshold results in a fan of lines for each lead in image space. A central point for each cluster in Fig. 4b was inverse-transformed to give an average representation of each lead (Fig. 3d). All prominent leads were detected, but several short or less prominent leads were not, because they do not have collinear points greater in number than the empirically chosen accumulator threshold of 51. The near-vertical line on the right in Fig. 3d is a false detection - at least 52 points lie on that line in image space. While lowering the threshold increases the probability of detecting all leads, the number of false detections rises also. Using smaller images mitigates this problem to some degree by lessening the chance that the number of randomly collinear points will exceed the number of points in the shortest lead. However, detection will always be biased toward longer (and straighter) leads.

In Fig. 5, inverse transforms for images 2-4 using accumulator cluster centers are shown. Thresholds were lowered until the first occurrence of a false detection, and then raised to prevent false detection.

#### 4. RESULTS

In order to display parameter space information as lead orientation and spacing, histograms of the frequency with which points occur on an image line are plotted (Fig. 6). The orientation histogram is found by summing the elements in columns of an accumulator such as that of Fig. 4b, in which points below the threshold have been set to 0. The normal length, or distance histogram, is found by summing

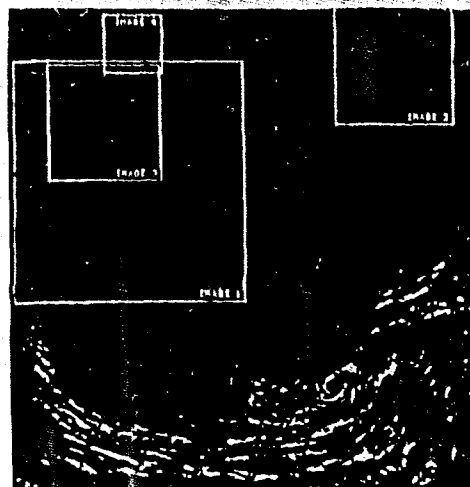


Fig. 2. NOAA-9 AVHRR image from 25 April, 1986, enhanced to highlight leads.

row elements. The distance histograms have peaks which are higher and sharper than those for orientation, in part because orientation may change greatly along a lead while the normal distance to the origin stays roughly the same. Both lead length and the number of leads having the same orientation or normal distance from the origin contribute to the histograms in Fig. 6. A smoothed version of the orientation histogram is plotted as a representation of average orientation. It is of note that for images 1 and 2, orientation peaks are separated by about 30 degrees. This is near the 28 degree intersection angle Marko and Thorson (1977) found characteristic of Arctic leads.

The spacing between peaks in the distance histogram is an approximate measure of lead spacing. The histogram is treated as a spatial series and a Fourier transform performed. Peaks in the smoothed amplitude spectrum plotted to the right of each distance histogram correspond to lead spacings. Unlike taking an average of lead spacings, this method distills spacing information while preserving the bimodal nature of lead spacings such as those in image 1.

#### 5. CONCLUSIONS

The Hough transform simplifies the analysis of images for lead statistics. It yields lead orientation and spacing information quickly and in a form which is easy to interpret. As demonstrated here, it is an incomplete method in that some pre-processing is required to produce a binary image, and post-processing must be done to extract average lead width and length. Within these limitations, the Hough transform permits semi-automated extraction of lead parameters from digital imagery. Future work will attempt to fully automate the procedure by setting the accumulator threshold using criteria to avoid false detections (e.g. Gerig, (1987)). In addition, the statistical accuracy of the method must be established.

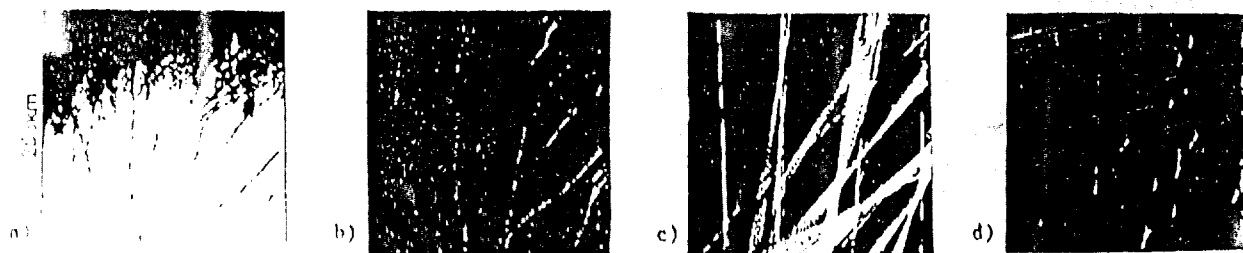


Fig. 3. Original image 1 (3a), binary image 1 (3b), inverse transform of accumulator points above a threshold of 51 (3c), and inverse transform of accumulator cluster centers only (3d).

#### REFERENCES

- Cress, A.M., "Detection of circular geological features using the Hough transform", *Int. J. Remote Sensing*, Vol.9, No.9, pp1519-1520, 1988.
- Ruda, R.O. and P. E. Hart, "Use of the Hough transformation to detect lines and curves in pictures", *Commun. ACM*, Vol. 15, No.1, pp11-15, 1972.
- Georg, G., "Limiting image space and accumulator space: a new approach for object recognition", in *Proc. 1st Int. Conf. Comput. Vision*, pp112-117, June 8-11, 1987.
- Harris, J.R., and R.E. Thomson, "Rectilinear leads and internal motions in the ice pack of the western Arctic ocean", *J. Geophys. Res.*, Vol.82, No.6, pp979-987, 1977.

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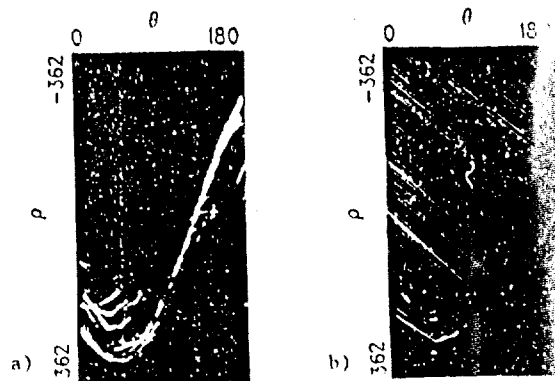


Fig. 4. Image 1 accumulator (4a) and accumulator with threshold applied (4b).

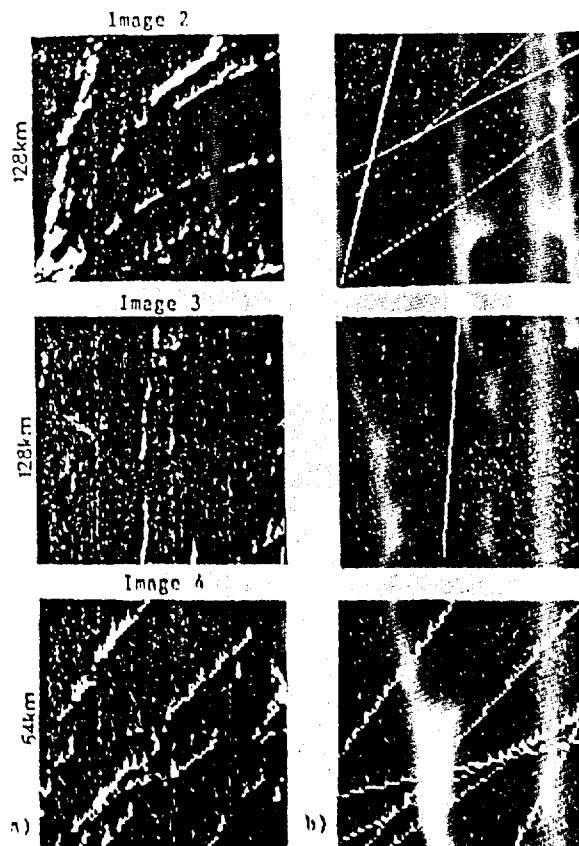


Fig. 5. Binary lead images (5a) and detected leads from accumulator peaks (5b) for images 2-4.

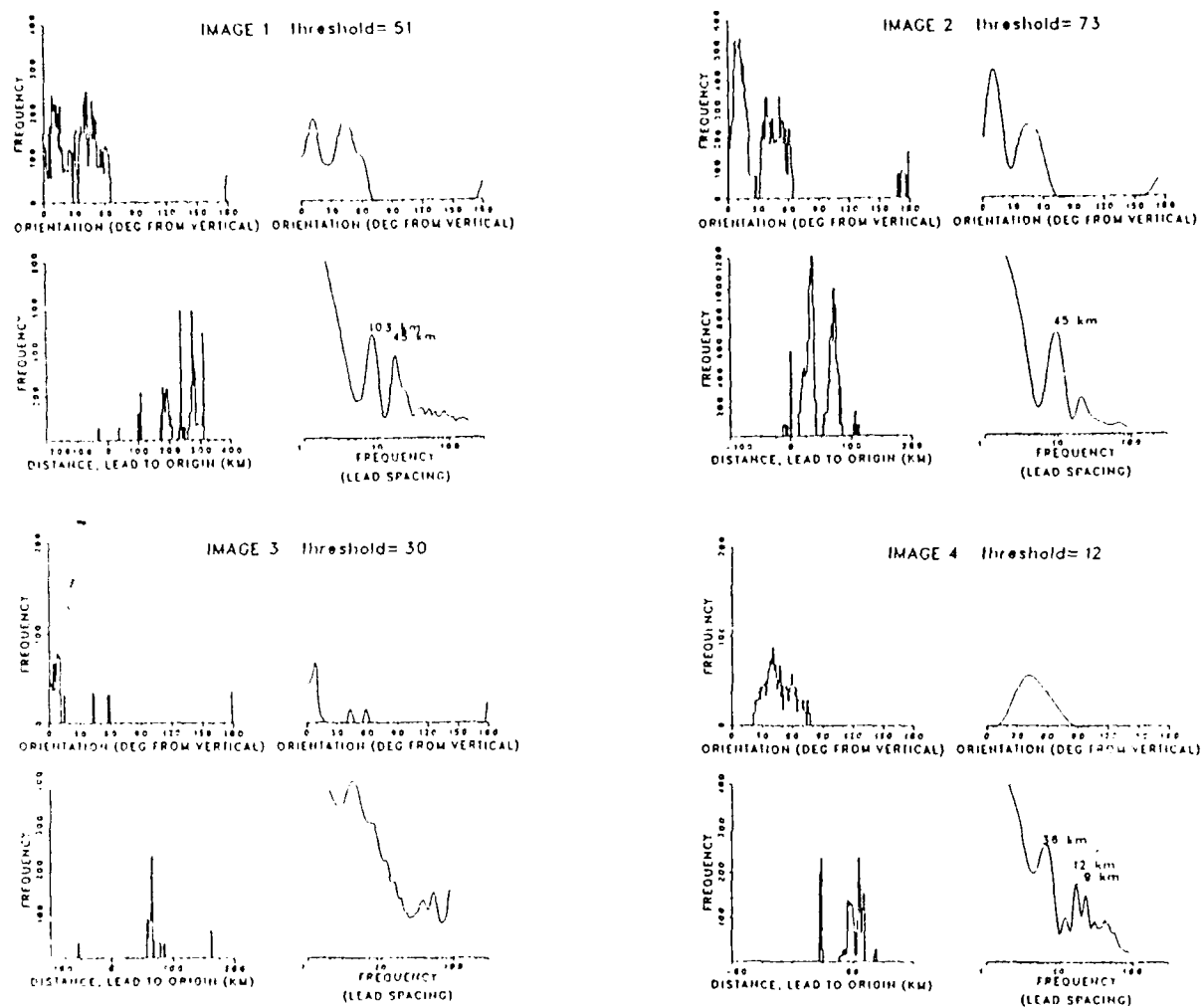


Figure 6. Lead orientation and spacing from Hough transform parameter space. Histograms on left, smoothed orientation histograms and smoothed Fourier transform of distance histograms on right.